

Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps

The European Standard EN ISO 13710:2004 has the status of a British Standard

ICS 23.080; 75.180.20

National foreword

This British Standard is the official English language version of EN ISO 13710:2004. It identical with ISO 13710:2004.

The UK participation in its preparation was entrusted by Technical Committee PSE/17, Materials and equipment for petroleum, petrochemical and natural gas industries, to Subcommittee MCE/6, Pumps and pump testing, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this subcommittee can be obtained on request to its secretary.

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Summary of pages

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Industries pétrolière, pétrochimique et du gaz naturel -
Pompes volumétriques alternatives (ISO 13710:2004)

This European Standard was approved by CEN on 1 June 2004.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration. Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

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Foreword

This document (EN ISO 13710:2004) has been prepared by Technical Committee ISO/TC 115 "Pumps" in collaboration with Technical Committee CEN/TC 12 "Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries", the secretariat of which is held by AFNOR.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2005, and conflicting national standards shall be withdrawn at the latest by January 2005.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Endorsement notice

The text of ISO 13710:2004 has been approved by CEN as EN ISO 13710:2004 without any modifications.

INTERNATIONAL STANDARD

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Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps

*Industries pétrolière, pétrochimique et du gaz naturel — Pompes
volumétriques alternatives*



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Contents

Page

Foreword	v
Introduction	vi
1 Scope	1
2 Normative references	1
3 Terms and definitions	4
4 General	8
4.1 Units of measurement	8
4.2 Subvendor control	8
5 Statutory requirements	8
6 Basic design	8
6.1 General	8
6.2 Selection of pump type	11
6.3 Ratings	11
6.4 Pressure-containing and pressure-retaining parts	15
6.5 Cylinder connections	16
6.6 External forces and moments	18
6.7 Liquid-end features	18
6.8 Power-end running gear	21
6.9 Direct-acting pump	22
6.10 Lubrication	23
6.11 Materials	24
6.12 Nameplates and rotation arrows	28
7 Accessories	29
7.1 Drivers	29
7.2 Couplings and guards	30
7.3 Belt drives	31
7.4 Mounting plates	32
7.5 Controls and instrumentation	34
7.6 Auxiliary piping	37
7.7 Pulsation and vibration control requirements	38
7.8 Special tools	39
8 Inspection, testing and preparation for shipment	40
8.1 General	40
8.2 Inspection	40
8.3 Testing	41
8.4 Preparation for shipment	43
9 Vendor's data	45
9.1 General	45
9.2 Proposals	46
9.3 Contract data	47
Annex A (informative) Pump material specifications	50
Annex B (normative) Vendor drawing and data requirements (VDDR) form	57
Annex C (normative) Pulsation and vibration control techniques	60
Annex D (informative) Reciprocating positive-displacement pump data sheets	65
Annex E (informative) NPIP and NPSH	68

Annex F (informative) **Inspector's checklist**..... **71**

Annex G (normative) **Lubrication system** **72**

Bibliography..... **74**

Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13710 was prepared by Technical Committee ISO/TC 115, *Pumps*, Subcommittee SC 3, *Installation and special application*, in collaboration with ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Introduction

This International Standard was developed from API Std 674, 2nd edition, 1995, with the intent that the 3rd edition of API Std 674 will be the same as this International Standard.

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

This International Standard requires the purchaser to specify certain details and features.

A bullet (•) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be shown on data sheets or stated in the enquiry or purchase order (see examples in Annex D).

In this International Standard, where practical, US Customary (USC) units are included in brackets for information.

Annex A lists typical materials standards used in pumps.

Annex B contains a form in which are listed the vendor drawing and data requirements (VDDR).

Annex C specifies techniques for pulsation and vibration control.

Annex D contains typical data sheets.

Annex E describes pump system interaction and explains the differences between NPIP and NPSH.

Annex F contains an inspector's checklist.

Annex G specifies requirements for the lubrication system.

Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps

1 Scope

This International Standard specifies requirements for reciprocating positive-displacement pumps and pump units for use in the petroleum, petrochemical and natural gas industries. It is applicable to both direct-acting and power-frame types.

This International Standard is not applicable to controlled-volume pumps and rotary pumps.

NOTE For controlled-volume pumps see API Std 675; for rotary pumps see API Std 676.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 7 (all parts), *Pipe threads where pressure-tight joints are made on the threads*

ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Dimensions, tolerances and designation*

ISO 261, *ISO general-purpose metric screw threads — General plan*

ISO 262, *ISO general-purpose metric screw threads — Selected sizes for screws, bolts and nuts*

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 286-2, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

ISO 724, *ISO general-purpose metric screw threads — Basic dimensions*

ISO 965 (all parts), *ISO general-purpose metric screw threads — Tolerances*

ISO 1328-1, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO 1940-1, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual imbalance*

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 5753, *Rolling bearings — Radial internal clearance*

ISO 6708, *Pipework components — Definition and selection of DN (nominal size)*

ISO 7005-1:1992, *Metallic flanges — Part 1: Steel flanges*

ISO 7005-2, *Metallic flanges — Part 2: Cast iron flanges*

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 10438 (all parts), *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries*

ISO 13707, *Petroleum and natural gas industries — Reciprocating compressors*

ISO 15649, *Petroleum and natural gas industries — Piping*

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

EN 287 (all parts), *Qualification test of welders — Fusion welding*¹⁾

EN 288 (all parts), *Specification and approval of welding procedures for metallic materials*

EN 13445 (all parts), *Unfired pressure vessels*

ABMA 7, *Shaft and housing fits for metric radial ball and roller bearings (except tapered roller bearings) conforming to basic boundary plan*²⁾

AGMA 2015-1, *Accuracy classification system — Tangential measurements for cylindrical gears*³⁾

AGMA 6010, *Standard for spur, helical, herringbone, and bevel enclosed drives*

AGMA 6091, *Standard for gearmotor, shaft mounted and screw conveyor drives*

AGMA 9002, *Bores and keyways for flexible couplings (inch series)*

API Std 526, *Flanged steel pressure relief valves*⁴⁾

API Std 541, *Form-wound squirrel cage induction motors — 250 horsepower and larger*

API Std 546, *Brushless synchronous machines — 500 kVA and larger*

API Std 611, *General-purpose steam turbines for petroleum, chemical, and gas industry services*

API Std 677, *General-purpose gear units for petroleum, chemical and gas industry services*

API RP 686, *Machinery installation and installation design*

ASA S2.19, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance, including marine applications*⁵⁾

1) Comité Européen de Normalisation, 36, rue de Stassart, B-1050 Brussels, Belgium.

2) American Bearing Manufacturers Association, 2025 M Street, NW, Suite 800, Washington, DC 20036, USA.

3) American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, VA 22314, USA.

4) American Petroleum Institute, 1220 L Street NW, Washington, DC 20005-4070, USA.

5) Acoustical Society of America, 35 Pinelawn Road, Suite 114 East, Melville, NY 11747, USA.

ASME Boiler and pressure vessel code, Section V, *Non-destructive examination*⁶⁾

ASME Boiler and pressure vessel code, Section VIII, *Rules for construction of pressure vessels, division 1*

ASME Boiler and pressure vessel code, Section IX, *Welding and brazing qualifications*

ASME B1.1, *Unified inch screw threads, UN and UNR thread form*

ASME B16.1, *Cast iron pipe flanges and flanged fittings classes 25, 125 and 250*

ASME B16.5, *Pipe flanges and flanged fittings NPS 1/2 through NPS 24*

ASME B16.11, *Forged fittings socket welding and threaded*

ASME B16.42, *Ductile iron pipe flanges and flanged fittings classes 150 and 300*

ASME B16.47, *Large diameter steel flanges NPS 26 through NPS 60*

AWS D1.1, *Structural welding code — Steel*⁷⁾

DIN 910, *Heavy-duty hexagon head screw plugs*⁸⁾

HI 6.6, *Reciprocating pump tests*⁹⁾

HI 8.1-8.5, *Direct acting (steam) pumps — Nomenclature, definitions, applications, and operation*

IEEE 841, *Standard for the petroleum and chemical industry — Severe duty totally enclosed fan-cooled (TEFC) squirrel cage induction motors — up to and including 370 kW (500 hp)*¹⁰⁾

NACE MR0175, *Sulfide stress cracking resistant metallic materials for oilfield equipment*¹¹⁾

NFPA 70:2002, *National Electrical Code*¹²⁾

SSPC SP 6, *Surface preparation specification*¹³⁾

6) American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA.

7) American Welding Society, 550 North LeJeune Road, Miami, FL 33136, USA.

8) Deutsches Institut für Normung E.V., Burggrafenstrasse 6, 10787 Berlin, Germany.

9) Hydraulics Institute, 9 Sylvan Way, Parsippany, NJ 07054, USA.

10) Institute of Electrical & Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA.

11) National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, TX 77084-4906, USA.

12) National Fire Protection Association, 1 Battery March Park, Quincy, MA 02269-9101, USA.

13) Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, PA 15222-4643, USA.

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
acoustical simulation
process whereby the acoustical characteristics of fluids and the reciprocating-pump dynamic flow influence are modelled

3.2
alarm point
preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action

3.3
anchor bolt
bolt used to attach the mounting plate to the support structure

NOTE The support structure is usually a concrete foundation or steel structure.

cf. **hold-down bolt** (3.6)

3.4
direct-acting pump
reciprocating pump consisting of a piston-powered drive end connected directly to a liquid end to which power is directly transmitted by the action of the motive fluid on the piston

NOTE A direct-acting pump can use steam, air, or gas as the motive fluid.

3.5
flammable liquid
liquid that has a closed-cup flash point below 37,8 °C (100 °F), as determined by recommended test procedures and apparatus

NOTE Suitable test procedures are e.g. those set forth in NFPA 30.

3.6
hold-down bolt
mounting bolt
bolt that holds the equipment to the mounting plate

3.7
inlet reference point
position, upstream of any pulsation suppression device, at which the purchaser's connection is made

NOTE At the inlet reference point the specified inlet conditions, such as inlet pressure, inlet temperature and NPIP, apply.

3.8
local
<of a device> mounted on the equipment mounting plate

3.9
maximum allowable speed
highest speed at which the manufacturer's design permits continuous operation

cf. **speed** (3.40)

3.10**maximum allowable temperature**

maximum continuous liquid temperature permitted by the manufacturer's design when handling the specified liquid at the specified maximum operating pressure

3.11**maximum allowable working pressure****MAWP**

maximum continuous pressure permitted by the manufacturer's design when handling the specified liquid at the specified maximum operating temperature

3.12**maximum continuous speed**

highest speed at which the machine, as built and tested, is capable of continuous operation with the specified liquid at any of the specified operating conditions

cf. **speed** (3.40)

3.13**minimum allowable liquid temperature**

lowest liquid temperature permitted by the manufacturer's design

3.14**minimum allowable speed**

lowest operating speed at which the manufacturer's design permits continuous operation

cf. **speed** (3.40)

3.15**mounting plate**

baseplate, skid or soleplate on which the equipment is mounted

NOTE See 7.4 for mounting plate specifications.

3.16**net positive inlet pressure****NPIP**

minimum instantaneous pressure determined at the pump inlet reference point during pulsating pressure, minus the vapour pressure of the liquid at the maximum operating temperature

3.17**net positive inlet pressure available****NPIPA**

NPIP determined by the vendor from the NPSHA and system data

3.18**net positive inlet pressure required****NPIPR**

minimum NPIP required by the pump to achieve the required performance with the specified liquid

3.19**NPIPR test**

running test conducted to validate the NPIPR

3.20**net positive suction head****NPSH**

total absolute suction pressure, determined at the underside of the mounting plate, minus the vapour pressure of the liquid

NOTE It is expressed as head of water, in metres (feet).

3.21

net positive suction head available

NPSHA

minimum value of NPSH determined to be available under any specified operating condition at the underside of the mounting plate, based on steady-state flow

NOTE NPSHA is a value provided by the purchaser which can be used by the supplier to calculate the NPIPA (see 3.17). NPSHA is a function only of the system upstream of the pump and the operating conditions, and is independent of pump design.

3.22

observed inspection [test]

inspection [test] for which the purchaser is notified of the timing, and the inspection [test] is performed as scheduled irrespective of whether the purchaser or purchaser's representative is present

3.23

panel

enclosure used to mount, display and protect gauges, switches and other instruments

3.24

performance test

running test conducted to confirm the pump's mechanical and volumetric efficiency

3.25

piston pump

reciprocating pump having a seal attached to the piston and moving within a cylinder

3.26

piston load

plunger load

force acting on one piston or plunger during any portion of the pumping cycle

3.27

plunger pump

reciprocating pump having a uniform-section plunger that moves in a static seal

3.28

power pump

reciprocating pump consisting of a power end and a liquid end connected by a frame or distance piece

NOTE 1 The power end of a power pump transmits energy from a rotating shaft to pistons or plungers by means of a crankshaft, connecting rods and crossheads.

NOTE 2 The liquid end of a power pump consists of the cylinders, the pistons or plungers, and the valves.

3.29

preliminary anticipated system acceleration head

estimated pressure change due to changes in fluid velocity in the piping system

NOTE This is an important factor in the application of reciprocating pumps because of the pulsating nature of the flow in the pump suction line. For additional information on acceleration heads, see Annex E.

3.30

pressure-containing part

part that acts as a barrier between process or motive liquid and the atmosphere

EXAMPLES Liquid cylinder, discharge manifold, suction manifold, stuffing box, cylinder plugs and covers (if in contact with process fluid), valve seats (if a portion is in contact with the atmosphere), power cylinder, gas cylinder head, valve chest, valve chest cover and heads.

3.31**pressure-limiting valve accumulation pressure**

pressure at which a pressure-limiting valve discharges the pump-rated flow

3.32**pressure-limiting valve set pressure**

pressure at which a pressure-limiting valve starts to release pressure

3.33**pressure-retaining part**

part whose failure would allow process or motive fluid to escape to the atmosphere

EXAMPLES Pressure-containing parts (3.30) and liquid and gas cylinder bolting, stuffing box bolting, gland bolting, glands, and covers that constrain plugs and valve stops, but not parts such as packing, gaskets, pistons, plungers, piston rings, rods, valves, seats (if completely surrounded by pressure-containing parts), and internal bolting.

3.34**pump efficiency****pump mechanical efficiency**

ratio of the pump's hydraulic power to its power input

3.35**purchaser**

issuer of the order and specification to the vendor

NOTE

The purchaser can be the owner of the plant in which the equipment is to be installed or the owner's appointed agent.

3.36**rated flow**

total volume of liquid actually delivered per unit time at rated operating conditions, normalised to inlet conditions

NOTE

Rated flow includes liquid and any dissolved or entrained gases or solids specified.

3.37**remote**

⟨of a control device⟩ located away from the equipment or console, typically in a control room

3.38**shutdown set point**

pre-set value of a measured parameter at which automatic or manual shutdown of the system or equipment is required

3.39**special tool**

tool that is not commercially available, e.g. from a catalogue

3.40**speed**

⟨power pump⟩ number of revolutions of the crankshaft in a given unit of time.

NOTE

It is expressed in revolutions per minute.

3.41**speed**

⟨direct-acting pump⟩ number of strokes of the piston in a given unit of time.

NOTE

It is expressed in strokes per minute.

3.42

unit responsibility

responsibility for coordinating the delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order

NOTE The technical aspects to be considered include but are not limited to such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications and testing of components.

3.43

vendor supplier

manufacturer or manufacturer's agent that is contractually responsible for the supply of the equipment

3.44

volumetric efficiency

ratio of the pump rated flow to the total piston or plunger displacements per unit time

NOTE Volumetric efficiency is normally expressed as a percentage.

3.45

witnessed inspection [test]

inspection [test] for which the purchaser is notified of the timing of the inspection [test] and a hold is placed on the inspection [test] until the purchaser or his representative is in attendance

4 General

4.1 Units of measurement

Drawings and maintenance dimensions of pumps shall be in SI units or US Customary (USC) units. Use of SI units on the data sheets indicates that SI units shall be used. Use of USC units on the data sheets indicates that USC units shall be used. See Annex D for typical data sheets.

4.2 Subvendor control

The vendor who has unit responsibility shall ensure that all subvendors comply with the requirements of this International Standard.

5 Statutory requirements

The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances or rules that are applicable to the equipment.

6 Basic design

6.1 General

6.1.1 The equipment (including auxiliaries, but excluding parts listed in Table 1, which are subject to wear and maintenance) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

It is recognised that these requirements are design criteria, and that service or duty severity, misoperation or improper maintenance can result in a machine failing to meet these criteria.

The term “design” shall apply solely to parameters or features of the equipment supplied by the manufacturer. The term “design” should not be used in the purchaser's enquiry or specifications because it can create confusion in understanding the order.

Table 1 — Maintenance items

Item	Life (months)
Packings	4 to 12
Valves	9 to 24
Valve seats	9 to 24
Plungers	12 to 36
NOTE The actual life of these parts will depend on the liquid, the service conditions and the installation method.	

6.1.2 The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

- **6.1.3** The purchaser shall specify the normal operating point and all other required operating points.

6.1.4 Equipment driven by fixed-speed induction motors shall be rated at the actual motor speed for the rated load condition.

- **6.1.5** Control of the sound pressure level (SPL) of all equipment supplied shall be a joint effort of the purchaser and the vendor having unit responsibility. The equipment supplied by the vendor shall conform to the maximum allowable sound pressure level specified. In order to determine compliance, the vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment.

6.1.6 Unless otherwise specified, the cooling water system or systems shall be designed for the conditions given in Table 2.

6.1.7 Provision shall be made for complete venting and draining of the pump and systems provided by the vendor.

6.1.8 Equipment shall be selected to run to the pressure-limiting valve accumulation pressure without suffering damage.

NOTE There might be insufficient driver power to operate under these conditions.

6.1.9 For direct-driven equipment, the equipment's maximum continuous operating speed shall be not less than 105 % of the rated speed for variable speed machines, and shall be equal to the rated speed for constant-speed drives.

6.1.10 For gear-driven equipment, the gearbox input shaft maximum continuous operating speed shall be not less than 105 % of the rated speed for variable speed machines and shall be equal to the rated speed for constant-speed drives.

6.1.11 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

Table 2 — Cooling water system design requirements

Parameter	SI units	USC units
Velocity over heat exchange surfaces	1,5 m/s to 2.5 m/s	(5 ft/s to 8 ft/s)
Maximum allowable working pressure (MAWP), gauge pressure	700 kPa	(7,0 bar) (100 psi)
Test pressure (1,5 MAWP)	1 050 kPa	(10,5 bar) (150 psi)
Maximum pressure drop	100 kPa	(1 bar) (15 psi)
Maximum inlet temperature	30 °C	(90 °F)
Maximum outlet temperature	50 °C	(120 °F)
Maximum temperature rise	20 K	(30 °R)
Fouling factor on water side	0,35 m ² K/kW	(0,002 hr-ft ² -°R/Btu)
Shell corrosion allowance	3 mm	(1/8 in)
To avoid condensation, the minimum inlet water temperature to water-cooled bearing housings should be above the ambient air temperature.		
The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimise water-side fouling; the criterion for minimum temperature rise is intended to minimise the use of cooling water. If such a conflict exists, the purchaser will approve the final selection.		

6.1.12 Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable sections of IEC 60079 or NFPA 70:2002, Articles 500, 501, 502, 504 and 505 as specified, as well as any local codes specified by the purchaser (the provision of which is the purchaser's responsibility).

6.1.13 Oil reservoirs and housings that enclose moving lubricated parts, such as bearings, shaft seals, highly polished parts, instruments and control elements, shall be designed to minimise contamination by moisture, dust and other foreign matter during periods of operation and idleness.

6.1.14 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as cylinder components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly. This may be accomplished by the use of shouldering, cylindrical dowels or keys.

6.1.15 The equipment (machine, driver and auxiliary equipment) shall perform on the test stand and on their permanent foundation within the specified test tolerances (see 8.3.5). After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility. The vendor shall review and comment on the purchaser's piping and foundation drawings in order to minimize adverse effects.

NOTE Many factors can adversely affect performance of the pump at site. These factors include piping layout, piping connection loads, alignment at operating conditions, support structure, handling during shipment, and handling and assembly at the site.

- **6.1.16** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions, and with the available utilities, specified by the purchaser. The environmental conditions shall include installation indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, maximum humidity, dusty or corrosive conditions.

6.1.17 Spare and replacement parts for the machine and all supplied auxiliaries shall meet all the criteria of this International Standard.

6.1.18 Bolting for cylinders shall conform to a) through f) below.

- a) The details of threading shall conform to ISO 261, ISO 262, ISO 724 and ISO 965, or to ASME B1.1.
- b) Adequate clearance shall be provided at all bolting locations to permit the use of socket spanners (wrenches).
- c) External or internal hexagon-head bolting is required unless otherwise agreed.
- d) Mounting bolts shall be not less than 12 mm (0,5 in) diameter.
- e) Manufacturer's markings shall be located on all fasteners 6 mm (1/4 in) and larger (excluding washers and headless screws). For studs, the marking shall be on the end of the stud at the same end as the nut.

NOTE A set-screw is a headless screw with a hexagonal socket in one end.

- f) Metric fine and UNF threads shall not be used.

6.1.19 Mounting surfaces shall meet the following criteria.

- a) They shall be machined to a finish of 6,3 μm (250 μin) arithmetic average roughness (R_a) or smoother.
- b) To prevent a soft foot, they shall be in the same horizontal plane within 25 μm (0,001 in).
- c) Each mounting surface shall be machined within a flatness of 1:24 000; corresponding surfaces shall be in the same plane within 150 $\mu\text{m}/\text{m}$ (0,002 in/ft).
- d) The upper machined or spot-faced surface shall be parallel to the mounting surface.
- e) Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces, machined or spot-faced to a diameter three times that of the hole and to allow for equipment alignment, be 15 mm (1/2 in) larger in diameter than the hold-down bolt.

6.1.20 Glands shall be bolted or threaded to the stuffing box. Gland studs shall pass through holes (not slots) in the gland. Axially-split glands shall be bolted together. Threaded gland bolts in slots are not acceptable.

6.2 Selection of pump type

Unless otherwise specified, a piston pump shall not be used in applications requiring continuous operation where the differential pressure across the piston is in excess of 15 MPa (150 bar) (2 175 psi).

NOTE Operation above these pressures might result in a significant reduction in piston seal and liner life and some reduction in pump performance (due to piston seal leakage).

6.3 Ratings

6.3.1 Table 3 and Table 4 represent the maximum allowable speed ratings for reciprocating pumps in continuous service.

Table 3 — Speed ratings for power pumps in continuous service

Stroke length		Speed rating	
mm	(in)	r/min	
		Single-acting pumps	Double-acting piston-type pumps
50	(2)	450	140
75	(3)	400	127
100	(4)	350	116
125	(5)	310	108
150	(6)	270	100
175	(7)	240	94
200	(8)	210	88
250	(10)	168	83
300	(12)	140	78
350	(14)	120	74
400	(16)	105	70

For single-acting plunger pumps with five or more cylinders, speeds may be increased by 20 % for continuous operation. For light and intermittent duties (up to 6 h per day), speeds up to 10 % higher are permissible.

Table 4 — Speed ratings for direct-acting pumps in continuous service

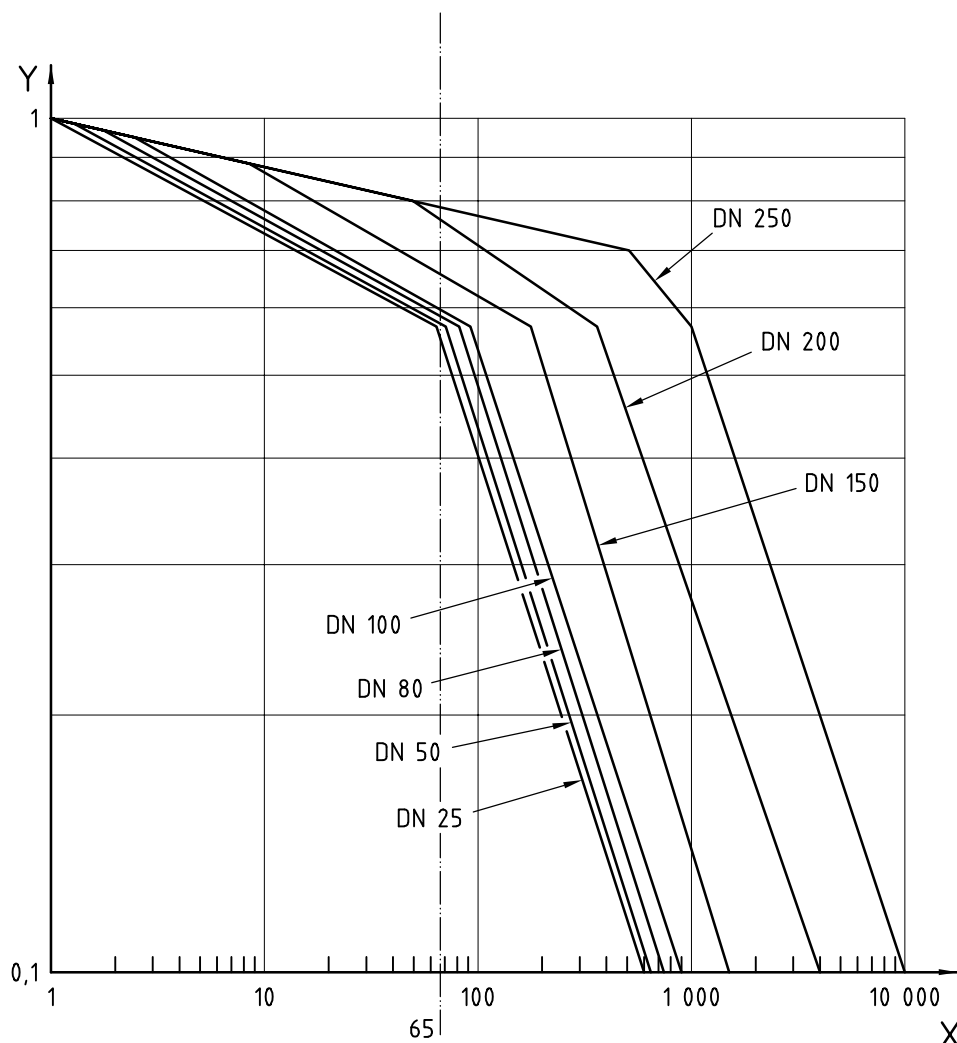
Stroke length		Speed rating
mm	(in)	strokes per minute
100	(4)	52
150	(6)	44
200	(8)	38
250	(10)	34
300	(12)	30
350	(14)	28
400	(16)	26
450	(18)	24
500	(20)	22
600	(24)	20

Factors such as viscosity, specific gravity, abrasiveness, vapour pressure, gas solubility or evolution in the pumped liquid, specified pressures and temperatures, or system acceleration (resulting NPSH) head may require further speed limitations.

For installations where the NPIPA is less than 15 kPa (0,15 bar) (2,25 psi) above the NPIPR, consideration should be given to speeds lower than those in Tables 3 and 4.

6.3.2 For kinematic viscosities above 65 mm²/s (65 cSt) (300 Saybolt Seconds Universal) at pumping temperature, the speeds given in Table 3 and Table 4 shall be reduced using the correction factors given in

Figure 1. These correction factors apply only to pumps with plate and plug valves; for other valve designs, refer to manufacturers' data.



Key

X Liquid viscosity, mm^2/s (cSt)
Y Speed correction factor

NOTE The correction factors apply only for viscosities above $65 \text{ mm}^2/\text{s}$ (65 cSt).

Figure 1 — Speed reduction factors for viscous liquids for standard pumps with plate and plug valves, for inlet connection sizes DN 25, 50, 80, 100, 150, 200 and 250 (NPS 1, 2, 3, 4, 6, 8 and 10)

- 6.3.3 The purchaser shall supply liquid properties. Based on these properties, the vendor shall state the volumetric efficiency.

6.3.4 In the determination of power-pump power requirements, the value of pump efficiency used shall be that value determined by the vendor for the specified operating conditions.

NOTE The power requirement is used for driver sizing.

6.3.5 For power pumps, the vendor shall include in the proposal the rated and maximum allowable continuous piston or plunger loads. The allowable peak or momentary load, if different from the continuous rating, shall also be specified.

6.3.6 For direct-acting piston pumps, without liquid-end tail rods, the vendor shall include in the proposal the maximum process liquid outlet stall pressure, the larger of the two values calculated as follows.

$$p_{st} = \frac{(d_m^2 \times p_m) + [(d_p^2 - d_r^2) \times p_1] - [(d_m^2 - d_r^2) \times p_e]}{d_p^2} \quad (1)$$

$$p_{st} = \frac{(d_p^2 \times p_1) + [(d_m^2 - d_r^2) \times p_m] - (d_m^2 \times p_e)}{(d_p^2 - d_r^2)} \quad (2)$$

where

- d_m is the motive piston diameter;
- d_p is the liquid end piston or plunger diameter;
- d_r is the rod diameter;
- p_e is the lowest motive fluid exhaust pressure;
- p_m is the highest motive fluid supply pressure;
- p_1 is the highest process liquid inlet pressure;
- p_{st} is the maximum process liquid outlet stall pressure.

NOTE Direct-acting pumps might require protection by pressure-limiting valves, in the process liquid and motive fluid circuits, if pressures greater than design can occur.

6.3.7 For direct-acting plunger pumps, without liquid-end tail rods, the vendor shall include in the proposal the maximum process liquid outlet stall pressure, the larger of the two values calculated as follows:

$$p_{st} = \frac{(d_m^2 \times p_m) - [(d_m^2 - d_r^2) \times p_e]}{d_p^2} \quad (3)$$

$$p_{st} = \frac{(d_p^2 \times p_1) + [(d_m^2 - d_r^2) \times p_m] - (d_m^2 \times p_e)}{(d_p^2 - d_r^2)} \quad (4)$$

where

- d_m is the motive piston diameter;
- d_p is the liquid end piston or plunger diameter;
- d_r is the rod diameter;
- p_e is the lowest motive fluid exhaust pressure;
- p_m is the highest motive fluid supply pressure;
- p_1 is the highest process liquid inlet pressure;

p_{st} is the maximum process liquid outlet stall pressure.

NOTE Direct-acting pumps might require protection by pressure-limiting valves, in the process liquid and motive fluid circuits, if pressures greater than design can occur.

6.4 Pressure-containing and pressure-retaining parts

6.4.1 General

Pressure-containing parts shall be designed in accordance with 6.4.2 or 6.4.3 (as selected by the vendor) and the bolting shall be in accordance with 6.4.4, to achieve the following.

- a) Operate without leakage or internal contact between rotating and stationary components (other than bearings and seals) while subject simultaneously to the MAWP (and corresponding temperature) and the worst-case combination of maximum allowable nozzle loads applied to all nozzles.
- b) Withstand the hydrostatic test.

6.4.2 The allowable tensile stress in the design of the pressure-containing parts for any material shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature and, for castings, multiplied by the appropriate casting factor for the type of non-destructive examination (NDE) as given in Table 5. The manufacturer shall state which material specification is being used as the source of the material properties (see Annex A), as well as the casting factors applied.

Table 5 — Casting factors

Type of non-destructive examination (NDE)	Casting factor
Visual, magnetic particle and/or liquid penetrant	0,8
Spot radiography	0,9
Ultrasonic	0,9
Full radiography	1,0

NOTE Application of these criteria seldom results in ultimate tensile strength or yield strength governing the design; fatigue strength usually governs the design.

6.4.3 Pressure-containing parts may be designed with the aid of finite-element analysis. The value of the stress intensity and deflections shall be assessed for acceptability at 150 % of MAWP. The allowable tensile stress shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature.

6.4.4 The allowable stress for bolts shall be used to determine the total bolting area based on hydrostatic load and gasket preload, as applicable. The preload stress shall not exceed 0,75 times the bolting material minimum yield strength.

NOTE Preloading is performed to prevent bolt fatigue failure under cyclic loading.

6.4.5 The pressure-limiting valve accumulation pressure shall not exceed the maximum allowable working pressure of the cylinder and shall not exceed 110 % of the specified pressure-limiting valve set pressure. Piping system pressure protection is the responsibility of the purchaser.

6.4.6 Cylinders, pressure-retaining parts and supports shall be designed to prevent detrimental distortion caused by the worst-case combination of temperature, pressure, torque, and allowable external forces and moments based on the specified operating conditions.

6.4.7 To prevent leakage in pressure-containing and pressure-retaining parts, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1,5 times the stud diameter. The use of threaded connections in pressure-containing parts shall be subject to the approval of the purchaser.

6.4.8 Jackscrews, guide rods, cylindrical alignment dowels and/or other appropriate devices shall be provided to facilitate disassembly and reassembly, if required by pump design. Guide rods shall be of sufficient length to prevent damage to the internals or studs during disassembly and reassembly.

If jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counter-bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

6.4.9 If cooling of cylinders is necessary, separate non-interconnecting jackets are required for cylinder bodies and cylinder heads. The cylinder cooling system shall be designed to positively prevent process fluid from leaking into the coolant.

6.5 Cylinder connections

6.5.1 Openings for all piping connections on cylinders shall be standard pipe sizes DN 20 (NPS 3/4) or larger and shall be in accordance with ISO 6708. The following sizes shall not be used:

DN 32, DN 65, DN 90, DN 125, DN 175 and DN 225 (NPS 1 1/4, NPS 2 1/2, NPS 3 1/2, NPS 5, NPS 7 and NPS 9).

6.5.2 All process connections shall be flanged or machined and studded, except where otherwise approved by the purchaser. All connections shall be suitable for the maximum allowable working pressure as defined in 3.11. Main inlet and outlet process connections shall be oriented as specified. Connections shall be integral with the cylinder or, for cylinders of weldable material, may be welded if agreed by the purchaser and the vendor.

- If specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawing shall show weld designs, size, materials, and preweld and postweld heat treatments.

6.5.3 Connections welded to the cylinder shall meet the material requirements of the cylinder, including impact values, rather than the requirements of the connected piping (see 6.11.1.16). All welding of connections shall be completed before the cylinder is hydrostatically tested (see 8.3.2).

6.5.4 Butt-welded connections, size DN 40 (NPS 1 1/2) and smaller, shall be reinforced by using forged welding inserts or gussets.

6.5.5 For connections other than main process connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding DN 40 (NPS 1 1/2) may be used with purchaser's approval as follows:

- a) on non-weldable materials, such as cast iron;
- b) if essential for maintenance (disassembly and assembly).

6.5.6 Pipe nipples screwed or welded to the cylinders should not be more than 150 mm (6 in) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS 1 1/2).

6.5.7 Unless otherwise specified, pipe threads shall be tapered threads conforming to ISO 7-1. Openings and bosses for pipe threads shall conform to ASME B16.5.

NOTE For purposes of this provision, ASME B1.20.1 is equivalent to ISO 7-1.

6.5.8 If specified, cylindrical threads conforming to ISO 228-1 shall be used. If cylindrical threads are used, they shall be sealed with a contained face gasket, and the connection boss shall have a machined face suitable for gasket containment.

6.5.9 Threaded connections shall not be seal-welded.

6.5.10 Threaded openings not connected to piping shall be plugged. Taper-threaded plugs shall be long-shank solid round-head, or long-shank hexagon-head bar stock plugs in accordance with ASME B16.11. If cylindrical threads are specified, plugs shall be solid hexagon-head plugs in accordance with DIN 910. These plugs shall meet the material requirements of the pressure cylinder. A lubricant that is suitable for the contained fluid and for the service temperature shall be used on all threaded connections. Thread tape shall not be used. Plastic plugs shall not be used.

6.5.11 Nozzle connections shall be in accordance with 6.5.11.1 to 6.5.11.12 as applicable.

6.5.11.1 Flanges shall conform to ISO 7005-1:1992, Series 1, including Annexes D and E or ISO 7005-2 Series 1 or ASME B16.1, B16.5, B16.42 or B16.47 Series B, as specified.

6.5.11.2 If ISO 7005-1 has been specified, materials shall be in accordance with ISO 7005-1:1992, Table D.1 (DIN) or Table D.2 (ASTM), as specified. The pressure/temperature ratings in ISO 7005-1:1992, Annex E, shall correspond to the materials specified.

NOTE ISO 7005-1:1992, Tables E.1 to E.4 cover materials in Table D.1, and Tables E.5 to E.21 cover materials in Table D.2.

- **6.5.11.3** If specified, ASME B16.47 Series A flanges shall be provided.

6.5.11.4 Cast iron flanges shall be flat-faced and, except as noted in 6.5.11.5, conform to the dimensional requirements of ISO 7005-2 and the flange finish requirements of ASME B16.1 or ASME B16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (NPS 8) and smaller.

6.4.11.5 Flanges other than those covered in ISO 7005-2 shall conform to the dimensional requirements specified in 6.5.11.1.

6.5.11.6 Flat-faced flanges with full raised-face thickness are acceptable on cylinders of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ASME are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of non-standard length, this requirement shall be identified on the arrangement drawing.

6.5.11.7 Flanges shall be full-faced or spot-faced on the back and shall be designed for through-bolting.

6.5.11.8 Machined and studded connections and flanges not in accordance with ISO 7005-1, 7005-2 or ASME B16.1, B16.5, B16.42 or B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs and nuts for these non-standard connections.

6.5.11.9 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel, or perpendicular, to the plane shown on the general arrangement drawing to within $\pm 0,5^\circ$. Studs or bolt holes shall straddle centrelines parallel to the main axes of the equipment.

6.5.11.10 All purchaser's connections shall be accessible for disassembly without requiring the machine, or any major part of the machine, to be moved.

6.5.11.11 The concentricity of the bolt circle and the bore of all flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion of the gasket into the fluid flow.

6.5.11.12 There shall be no openings (other than suction or discharge ports) in the pumping-chamber sides of the liquid end or in other highly stressed areas subject to cyclic loading unless they are essential for pump operation or performance monitoring.